EFFECT OF AMBIENT TEMPERATURE ON DURATION OF GESTATION AND CHANGES IN RUMEN TEMPERATURE AT PARTURITION AND ESTRUS IN FALL CALVING BEEF COWS

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"In his heart a man plans his course, but the LORD determines his steps." Proverbs 16:9.

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CHAPTER I

INTRODUCTION

Gestation of beef cows averages 283 d and can be influenced by breed, genetics, number of calves, sex of calf, and environment (Cundiff et al., 1998). Parturition is initiated by the calf; the fetal hypothalamus secretes corticotropin releasing hormone which causes secretion of corticotropin by the pituitary and cortisol by the adrenal gland (Wagner et al., 1974). Increased cortisol in plasma of the dam initiates a cascade of events in the cow, including reduced production of progesterone by the placenta and/or corpus luteum, increased concentrations of estrogen and cortisol in plasma, and parturition. A decrease in body temperature may occur before parturition (Wrenn et al., 1958; Lammoglia et al., 1997a; Prado-Cooper et al., 2008).

In 2007, there were an estimated 37 million calves born in the United States, and 27.6% were born in the fall (USDA, 2008). Fall calving in Oklahoma may occur between August and December. During five years, cows at the Oklahoma Agriculture Research South Range that calved in August had a shorter gestation (277.7 ± 1.4 d, $P < 0.05$) compared with cows that calved in October (281.9 ± 2.3; Table 1). Weather conditions, especially temperature, change dramatically during these months and may influence duration of gestation. Ambient temperatures at our research location, near Stillwater, OK average of 33.9 °C in August 2007 (range of 18.3 to 38.3 °C), an average of 28.9 °C in September (range of 10.6 to 33.3 °C, and an average of 24.4 °C in October (range of 1.6 to 32.8 °C, (Mesonet, 2007). Kastner et al. (2004) observed shorter gestations in fall calving cows exposed to elevated ambient temperatures. Exposure of cattle to elevated ambient temperatures may also reduce productivity and reproductive performance. Fall calving in Oklahoma can be profitable. Warm season grasses are usually abundant during late gestation and at calving. This results in a greater body condition of cows at calving and during rebreeding, compared with spring calving cows. When fall calves are weaned in late spring or early summer, there are fewer calves marketed and weaned calf prices are usually greater. Although a fall calving season can be profitable, it is necessary to take into account the effects of elevated ambient temperatures in August and early September on duration of gestation and cow performance. Calves born in the fall tend to have reduced birth weights compared with spring calves (Selk and Buchanan, 1990). A decreased birth weight could be caused by altered placental function during heat stress or shorter gestation. Reduced birth weight could influence postnatal growth and development.

The objectives of this study were to evaluate the effects of ambient temperature on duration of gestation in beef cows by measuring maternal plasma concentrations of progesterone, cortisol and estradiol during late gestation. Rumen temperature changes at parturition and estrus will also be evaluated.

CHAPTER II

REVIEW OF LITERATURE

Duration of gestation, hormone in the calf and cow at parturition and changes in rumen temperature at parturition and estrus in beef cows

Duration of gestation in cattle can be affected by breed, genetics, sex of calf, number of calves, age of the dam, and environment. If cattle producers know the expected calving date cows can be observed for signs of calving difficulty and assisted if necessary. Long gestations decrease cow productivity and extend calving intervals. However, if gestation is shortened due to a stressor or a problem with a calf, the resulting parturition and calf could have problems. This review will examine the many influences and hormonal mechanisms which influence the duration of gestation and the change in body temperature at parturition and estrus in cattle.

Breed influence on duration of gestation

Breeds of cattle have evolved over the centuries according to man's needs through domestication and selective breeding. Duration of gestation is highly correlated with calve birth weight, and longer gestations result in heavier calves (Cundiff et al., 1986). Holsteins and Simmentals, which are large breed cattle, have gestations of 282 d to 286 d, respectively (Burfening et al., 1978; Fisher and Williams, 1978; Notter et al., 1978). Angus and Red Angus cattle, have gestations from 278 d to 282 d and lighter mature weight than Holsteins and Simmentals (Bourdon and Brinks, 1982; Larsen et al., 1994). Crossbred calves often have a longer gestation then purebred calves (Wheat and Riggs, 1958; Sacco et al., 1990). Gestation length is more heritable from the sire than the dam, so a bull with a short gestation bred to a cow with a long gestation would result in a calf with duration of gestation more similar to the bull than the cow (Bellows et al., 1971). The effects of heterosis for duration of gestation indicate that there may be a dominance effect associated with most traits for gestation, parturition and calf survival (Gregory et al., 1991). Hereford cows have a gestation of 285 d where as Brahman-Hereford crossbred calves have a longer gestation of 287 d (Wheat and Riggs, 1958). Pure breed Brahman cows have a gestation of 289 to 292 d which is longer than the Brahman cross cows mentioned earlier (Plasse et al., 1968; Notter et al., 1978). Gestation length within a herd can be influenced by selection for low birth weight which is synonymous with shorter duration of gestation.

Heritability and genetics of gestation

Factors that influence heritability of duration of gestation include breed, sex of calf, and genetics. Heritability of gestation length ranges from intermediate to highly heritable (Fisher and Williams, 1978; Bourdon and Brinks, 1982; Gregory et al., 1991). Duration of gestation and birth weight within breeds is highly heritable (Cundiff et al., 1986). Sire or paternal effect for gestation length have a greater heritability than maternal traits (Everett and Magee, 1965; Deutscher and Slyter, 1978). Repeatability of duration of gestation is greater in full sibs than for half sibs due to the greater heritability of paternal gestation length. Cows mated to the same bull have a greater repeatability of gestation length then cows mated to different bulls (Wheat and Riggs, 1958). Therefore a herd of cows bred to the same sire should have a more consistent duration of gestation than cows breed to several bulls. Artificial insemination of a herd of cows to one bull will produce a more uniform duration of gestation and calves compared with breeding to multiple sires.

Sex of calf effect on gestation

Bull calves have a longer duration of gestation than heifers. Birth weight and length of gestation are correlated; therefore bulls calves are heavier at birth than heifer calves (Bellows et al., 1971; Batra and Touchberry, 1974). Burfening et al., (1978) examined calving ease and discovered that not only did bull calves have a 1.7 d longer gestation on average compared with heifers but bull calves weighed 2 kg more compared with heifers at birth. Although there was no evidence of a sex of calf effect on calving ease, birth weight was a significant factor. Therefore cows carrying a bull calf are more likely to need assistance during parturition. Duration of gestation in Angus x Hereford calves was also greater for bulls than heifers by 1.9 d and bulls were 2.6 kg heavier than heifers (Bellows et al., 1971). Similar to Burfening's study, Bellows et al. (1971) also observed that bull calves required more assistance at birth than heifer calves due to the greater birth weight. Birth weight increased 0.25 kg/d during late gestation, but in the final days of normal gestation, birth weight increases at a slower rate (Burfening et al., 1978). There is no conclusive evidence that bull calves have a valuable advantage with an increased duration of gestation compared with heifer.

Gestation with single or twin calves

A major cost of beef production is the amount of feed required for maintenance of the cow herd therefore production of twins could be more profitable than single calves. An undesirable consequence of twinning is a shorter duration of gestation. Echternkamp et al. (1999) found that duration of gestation was reduced by 5.7 d for cows with twin compared with single calves and cows with twins had a greater incidence of retained placenta. Duration of gestation for twins ranged from 256 to 291 d compared with singles which range from 258 to 300 d (Gregory et al., 1990). Gregory et al. (1990) observed a decreased survival rate for calves with a gestation of less than 272 d and a decreased survival rate for twins at birth, and at 72 h, and 100 d of age. Fall born twins had a reduced survival rate attributed to possible heat stress and greater in utero effect of environment for dams of twins compared with singles (Gregory et al., 1990). It is possible that the extreme heat stress was causing blood to be diverted from the uterus to the surface of the body to assist in dissipating heat and this may limit nutrients available to the fetuses. Sex of calves effects duration of gestation in singletons however sex of twins did not have an effect on duration of gestation (Echternkamp and Gregory, 1999). Birth weight of twins increased at a rate of 0.45 kg per day as duration of gestation increased which was less than for single calves with a weight increase of 0.59 kg/d (Echternkamp and Gregory, 1999).

Effect of cow age on gestation

Beef heifers are usually bred to calve at 2 years of age and are expected to have a calf every 12 mo until they are no longer able to rebreed or produce a profitable calf. Heifers have a shorter duration of gestation than multiparous cows and calves produced by heifers weigh less at birth (Everett and Magee, 1965; Fisher and Williams, 1978; Bourdon and Brinks, 1982). Bourdon et al (1982) observed that gestation length was associated with an increase in age up to and including 5 yr old cows and calves from older cows had a greater birth weight than calves from younger cows up to 10 yr of age. Cows that were 11 yr of age and older had a shorter average duration of gestation and lighter birth weights than younger cows (Bourdon and Brinks, 1982). Fisher et al. (1978) found that second calves were 2.8 kg heavier than first calves, and third calves were 0.8 kg heavier than second calves. Eight year old cows had calves with greater birth weights than 2 yr old cows and a longer duration of gestation (Everett and Magee, 1965). The age and maturity of the cow has an effect on the nutrients available to the calf for growth and development.

Environmental effects on gestation

Environment of a pregnant cow can include nutrition, housing conditions, and weather factors such as ambient temperature and humidity. This review will evaluate the effect of weather and nutritional factors associated with duration of gestation. Elevated ambient temperatures can cause heat stress when the environmental temperature is greater than the animal's thermo neutral zone (Armstrong, 1994). Heat stress at the time of insemination decreases conception rate in cows. Morton et al. (2007) observed that conception was reduced by exposure of cows to heat stress from 1 mo before the day of service to 2 wk after the day of service. Exposure to elevated ambient temperatures during early pregnancy results in reduced fetal weight and may increase embryonic mortality (Biggers et al., 1987). Ewes exposured to heat stress during late gestation had dwarf lambs and reduced birth weight (Brown et al., 1977). Heat stress of beef cows in late gestation can cause a significant decrease in duration of gestation and birth weight (Kastner et al., 2004). The days of gestation and the duration of heat exposure that alter the duration of gestation and birth weight have not been established. Physiological and nutritional stress of ewes in early gestation causes a decrease in crown-rump length of the fetus and duration of gestation (Smith et al., 2008). Reduced nutrients of ewes in early gestation with twin pregnancies results in early parturition and cannot be reversed by an increase in maternal diet later in gestation (Edwards and McMillen, 2002).

Parturition in beef cows

Parturition is the process by which the fetus is expelled from the uterus into the external environment. It requires endocrine and physiological changes in both the fetus and the dam. Parturition is initiated by the fetus with the release of ACTH from the fetal pituitary (Wagner et al., 1974). The fetal adrenal is then stimulated to produce cortisol which will cross the placenta to the maternal system. The release of cortisol into the maternal system results in a cascade of events. Progesterone production by the placenta is decreased along with a decrease in progesterone from the CL on the ovary. The CL is maintained throughout pregnancy to produce progesterone and is required until the seventh month of pregnancy in the bovine (Estergreen et al., 1967; Tanabe, 1970; Smith et al., 1973). Estrogen production will increase from the placenta as a result of the decreased progesterone (Smith et al., 1973). The uterus increases production of prostaglandin $F_{2\alpha}$ which causes uterine contractions to begin (Wagner et al., 1974). Oxytocin is released from the maternal pituitary causing the cervix to dilate, fetal membranes to detach and uterine muscles to contract (Wagner et al., 1974). The release of oxytocin is pulsatile and increases in frequency and intensity the day of parturition (Fuchs et al., 2001). As contractions increase in intensity and frequency the fetus will move up the birth canal and the chorioallantois will rupture. The amnion will also rupture as the fetus begins to emerge from the birth canal. Once the fetus has cleared the birth canal the fetal membranes follow and contractions will continue to push out all fetal membranes.

Role of the fetus during parturition

A fetus must become an independent life form at birth. It loses the safety and support of the uterine environment at birth and must now breathe, consume nutrients, and become mobile on its own. While in the uterus the fetus is supplied with oxygenated blood that has been filtered by the maternal system and the placenta. The fetus has little renal function while in the uterus despite consuming amniotic fluid and no respiratory activity (Trahair et al., 1987). Fetal membranes are established early in gestation to provide nutrients and respiratory support for the fetus as it grows. Fetal membranes and placental growth occurs primarily in the first half of gestation, but vascular development continues throughout gestation to accommodate the increased needs of the fetus (Reynolds and Redmer, 1995). Fetal organs are being differentiated at this time as hyperplasia is the major form of growth during the first trimester (Gore et al., 1994). The second trimester is marked by an increase in hypertrophy of the fetal organs and tissues (Godfredson et al., 1991). In the third trimester the fetus will grow and mature its organs and systems in preparation for birth (Mao, 2008). Cortisol is vital for the maturation and development of many organs of the fetus (Bassett and Thorburn, 1969). Progesterone and estrogen produced by the placenta and CL are essential for preparing the uterus to expel the fetus and stop the flow of nutrients to the uterus that was once supporting the fetus and is not necessary when the dam is not pregnant (Smith et al., 1973).

Cortisol in the fetus at parturition

Cortisol is produced by the adrenal gland. The production of cortisol is stimulated by ACTH which is produced and secreted from the anterior pituitary (Wagner et al., 1974). Production of cortisol is also the mechanism that initiates parturition.

Concentrations of cortisol in plasma of cows increase dramatically the day of parturition (Smith et al., 1973). The hypothalamus of the calf matures and is activated when it is time for parturition to begin. The hypothalamus of the calf releases ACTH which acts on the fetal adrenal to produce cortisol. Despite the dramatic increase in fetal cortisol at the time of parturition there is little effect on maternal concentrations of cortisol with the highest concentrations in the fetus at birth well above maternal concentrations (Bassett and Thorburn, 1969). It has been speculated that the normal negative feedback of cortisol on ACTH in the fetus is not functional before birth in both livestock and primates until after birth (Challis and Brooks, 1989; Ellmann et al., 2008). This may occur to ensure activation of hormonal and enzymatic processes that must take place throughout the uterus. Cortisol attaches to receptors on the placenta and reduces the production of progesterone and increase production of estrogen, prolactin, and oxytocin. Anderson et al., (1975) observed increased concentrations of cortisol in plasma of sheep may be important to begin the biosynthesis of estrogen from progesterone and induce catabolism of placental progesterone prior to parturition.

Cortisol is necessary for the maturation of the fetal lungs, which must support respiration at birth. Sheep, pigs and rabbits must complete at least 90% of their gestation period for the lungs to mature and function to support the fetus (Olson, 1979). Thyroid releasing hormone (TRH) and prolactin increase along with cortisol, prepartum for lung maturation (Liggins et al., 1988). Surfactant is synthesized and secreted in the lungs of the fetus in response to cortisol. Surfactant covers the alveoli to provide the lungs with stability when breathing by helping the lung resist collapse.

Cortisol is also required for the maturation of the small intestine. Sheep fetuses administered cortisol before 115 d of gestation had premature maturation of villi in the small intestine which normally would occur late in gestation (Trahair et al., 1987). Exposure of the fetus to cortisol during late gestation is necessary for the function of lungs and digestive system at birth.

Maternal role during parturition

The fetus initiates parturition but the dam is responsible for expelling the fetus by contractions of the uterus and termination of the fetal/maternal tissue connections. Progesterone production by the placenta and the CL decreases at parturition and estrogen production by the placenta increases. After the fetus has initiated parturition the dam must prepare to nurse the fetus. Mammals must produce milk to support young until young are able to consume and digest nutrients from the environment. Increased concentrations of prolactin at the time of parturition stimulate the mammary glands to synthesize colostrum and milk (Pennington and Malven, 1985). Oxytocin is also involved in uterine contractions and dilation of the cervix for passage of the fetus (Wagner et al., 1974). Prostaglandin $F_{2\alpha}$ is produced by the uterus at parturition, stimulates uterine contractions and terminates the connections between the fetal membranes and the uterus (Wagner et al., 1974) . The major role of the dam at parturition is to expel the fetus and membranes. Fetal hormones act on the maternal system to activate changes in the ovary and/or uterus of the dam to initiate parturition.

Progesterone at parturition

Progesterone is produced by the placenta and the CL on the ovary. The CL formed at ovulation is maintained if fertilization occurs and produces progesterone until parturition begins when it regresses, reducing progesterone production. The CL is essential to maintain pregnancy until 7 mo of gestation then the placenta produces sufficient progesterone to maintain pregnancy. If the CL is removed before 7 mo gestation may be shorter than normal or result in retained placental membranes (Estergreen et al., 1967; Tanabe, 1970). During late gestation concentrations of progesterone in plasma are constant and similar to the maximum found during the luteal phase of the estrous cycle (Stabenfeldt et al., 1970; Robertson, 1972; Smith et al., 1973). The placenta produces progesterone to assist in the maintenance of pregnancy until the release of cortisol near parturition. Progesterone receptors located in the caruncule appear to be under the control of placental progesterone in late gestation rather than progesterone produced by the CL (Schuler et al., 1999). The control of progesterone receptors by the fetus could be another indicator of fetal control of parturition. Schuler et al., (1999) did not find a difference in progesterone receptors in cotyledons until the time of parturition. Progesterone begins to decrease a few days before parturition in sheep and cattle (Smith et al., 1973). Concentrations of progesterone in plasma at parturition are usually < 1 ng/mL (Stabenfeldt et al., 1970; Robertson, 1972). Concentrations of progesterone after parturition are minimal until ovulation and/or luteinization of follicles occurs (Robertson, 1972).

Estrogen at parturition

Concentrations of estradiol in plasma increases prior to parturition (Smith et al., 1973). Estrogen is produced by the placenta in response to the release of cortisol from the fetus (Smith et al., 1973). The addition of estrogens to the induction protocol reduced retained placentas in both heifers and cows (Garverick et al., 1974; Muller et al., 1975;

Davis et al., 1979). A low concentration of estrogen at the induction of parturition may cause retention of the placenta (Garverick et al., 1974). Estrogen receptors on the placentomes and caruncles are present at their highest concentration at the time of parturition in cows that have been induced after 269 d of gestation (Boos et al., 2000). Receptors for estrogen must be present before parturition so the fetal membranes can respond to estrogen and be detached and expelled from the uterus.

Cortisol in the dam at parturition

Concentrations of cortisol in plasma of cows are not related to the fetal cortisol concentrations. Only 10-20% of maternal cortisol will pass through the placenta into the fetal circulation (Hudson et al., 1976; Boos et al., 2000). Glucocorticoid receptors in the caruncles are involved in the initiation of parturition and the release of fetal membranes (Boos et al., 2000). Cotyledons are stimulated at the initiation of parturition for proper release of fetal membranes. Maternal cortisol increases at the time of parturition then decreases to basal concentrations within 12 h related to the act of labor in the dam (Smith et al., 1973; Hudson et al., 1976).

Prolactin at parturition

Prolactin release increases near the time of parturition and is thought to be involved in several biological pathways in the fetus and the dam. Milk production is stimulated but not dependent on prolactin. Induced parturition causes an increase in concentrations of prolactin in milk but has no effect on concentrations of prolactin in plasma (Erb et al., 1977).

Rumen Temperature at parturition

Predicting parturition is a valuable tool for cattle management. The ability to predict parturition would enable assistance to cows with calving difficulty. A decrease in body temperature may occur before parturition (Wrenn et al., 1958; Sawada et al., 1988; Lammoglia et al., 1997a; Aoki et al., 2005; Prado-Cooper et al., 2008). It is unclear what causes the decrease in body temperature. There is a cascade of hormonal changes that occur at parturition including a decrease in concentrations of progesterone and increases in estrogen, PGF2α, oxytocin and relaxin in the maternal blood that could related to the decrease in body temperature at parturition. Lammoglia et al (1997a) found that sex hormones were not related to body temperature at parturition by measuring temperature under the skin at the flank. Exogenous progesterone causes an increase in body temperature and may have a role in the cyclic temperature changes associated with CL function (Wrenn et al., 1958). Based on this observation body temperature should decrease at parturition due to a decrease in concentration of progesterone in plasma. There was no difference in the drop in vaginal temperature for cows with twins compared with cows with singles births (Aoki et al., 2005). The decrease in body temperature at parturition has been confirmed by several studies however the cause and predictability are not established. Body temperature must be recorded multiple times a day to get an accurate temperature measurement for an individual cow. Prado-Cooper (2008) used rumen temperature bolus to record temperature at 15 min intervals to study the change in rumen temperature at parturition. She found a decrease in rumen temperature ≥ 0.3 °C the day before parturition in spring calving beef cows (Prado-Cooper et al., 2008). If a decrease of ≥ 0.3 °C occurs in cows preceding parturition, this could be used to accurately predict the time of parturition.

Estrus in cows

Estrous detection in cattle is essential for accurate and efficient AI and herd management. There are over 45 million breeding age cows in North America and of those 24.8% are bred by AI (Thibier and Wagner, 2002). The number of cows being artificially inseminated has increased with the demand for superior genetics for higher quality beef and dairy products. The U.S. dairy industry alone loses more than $300 million annually due to failure to detect estrous or false diagnosis of estrus (Senger, 1994). Methods of estrus detection must be improved to prevent losses in the beef and dairy industries related to breeding and reproduction in cows.

Estrus is the time during the estrous cycle when a female is receptive to breeding and displays behavioral signs along with hormonal changes which precede ovulation (White et al., 2002b). Estrous behavior can be seen when a cow stands to be mounted by another cow or bull. Other signs of estrus include discharge of vaginal mucus, swelling of the vulva, and increase activity. Plasma concentrations of estradiol are greatest during estrus phase of the cycle (Wettemann et al., 1972). Estradiol is produced by the follicle on the ovary which is stimulated by luteinizing hormone (LH) and follicle stimulating hormone (FSH) (Ireland et al., 1984). As the follicle grows concentrations of estradiol in plasma increase and estrous behavior is exhibited. Estradiol concentrations are greater from 3 d before to 3 d after estrus (Garverick et al., 1971; Wettemann et al., 1972). After ovulation the follicle lutenizes to become a CL which produces progesterone. Plasma concentrations of progesterone increase after estrus until 5 d prior to estrus at which time concentrations decrease with regression of the CL (Swanson et al., 1972; Wettemann et al., 1972). If a cow becomes pregnant, the concentration of progesterone will remain elevated and the CL will be maintained. However if the cow does not become pregnant at 14 d after estrus, the CL will regress, progesterone production will decrease, FSH and LH will stimulate a dominant follicle to grow and produce estradiol until ovulation occurs (Rajamahendran and Taylor, 1991a). Greater conception rates occur when AI is done between 4-18 hours after ovulation (Maatje et al., 1997; Dransfield et al., 1998).

Observation of cows for mounting and riding one another is a common method of estrus detection. Visual detection is usually done 2 or 3 times per day for 15 to 30 min and cows in estrus may be overlooked or missed if they are not exhibiting visual signs of estrus during the observation period. Some cows do not stand to be mounted even when in estrus and secondary signs must be detected or these animals will be considered not in estrus (Foote, 1975). Other methods for estrus detection include tail marking and color changing pressure-sensitive mount detectors. Tail marking or pressure-sensitive mount detectors must be monitored frequently and are subjective but can improve estrous detection compared with only visual detection (Baker, 1965; Holmann et al., 1987). Dairies have the advantage of being able to collect daily milk samples from each cow to test concentration of progesterone in milk as an indicator estrus but this is not feasible in a beef herd and can be costly (Holmann et al., 1987; Heersche and Nebel, 1994). Pedometers are also used to monitor estrus by recording an increase in activity which is positively correlated with estrus (Pennington et al., 1986; Peralta et al., 2005). Technology has recently offered the cattle industry a telemetric method of estrous detection like Heat Watch ®, which sends a signal back to a computer to record when a cow is mounted and the number of mounts, duration of mounts and duration between mounts (White et al., 2002a; Peralta et al., 2005). This information can be used to determine or predict the onset of estrus.

Rumen temperature at estrus

Body temperature of cows increases during estrus and this can be used to detect estrus. Rajamahendran et al. (1991a) observed a relationship between standing estrus and both rectal and vaginal peak temperatures but found no correlation with time of ovulation. This disagrees with a previous study by Rajamahendran et al. (1989) in which vaginal temperature but not rectal temperature was highly correlated with time of ovulation. Vaginal temperature was taken every 4 h during the study compared with Clappers et al. (1990) in which temperature was only taken twice daily. Clapper et al. (1990) was able to determine that a vaginal temperature increase of ≥ 0.3 °C occurs at estrus and the temperature increase was sustained for 8.14 ± 3.48 h. Onset of the temperature increase was most closely related to LH surge. Ovulation occurs within a consistent interval after LH surge confirming that temperature may be a good predictor of ovulation in all seasons (White et al., 2002b).

Estrus is often associated with an increase in activity. Cows not in estrus respond to the estrus cow and this can increase temperature of diestrus cows giving false positives for estrous detection by change in rumen temperature (Pennington et al., 1986). However the temperature increase due to participating in estrous activity was a short increase and not as elevated or prolonged as active cows in estrus (Walton and King, 1986a). Silent estrus or estrus with no external signs or behaviors was also detected by monitoring abdominal temperatures; an increase of 0.6 to 0.8 °C occurred at estrus, and resulted in successful conceptions when cows were AI (Zartman and Dealba, 1982a).

External methods for measuring changes in body temperature at estrus have not been as efficient or accurate as internal temperature measurement. Infrared scanning to measure the magnitude of temperature change results in excess false positives (Hurnik et al., 1985). Ear temperature measurements were also inconclusive and are not a good measure of a cow's body temperature changes (Redden et al., 1993a). Milk temperature has also been evaluated to determine estrus in dairy cows. Fordham et al. (1988) discovered an increase in milk temperature by at least 0.2 °C at estrus compared with temperature of the three previous days. Milk temperature does vary throughout the day and can be affected by many factors including milk flow and distance from udder where temperature is taken. Vaginal temperature was higher than milk temperature for all measurement points indicating milk temperature may not be a good representative of body temperature or useful in estrous detection (Fordham et al., 1987). Body temperature could be used to evaluate estrus with frequent records of the core body temperature averaged over a period of time and compared to previous periods.

It is established that temperature readings need to be measured more frequently to give a more accurate understanding of temperature changes in a cow's body. Rumen boluses provide non-invasive, frequent measurements of core body temperature which is sent back to a computer for record keeping and analysis. In addition, rumen boluses could be used to monitor animal health, water intake and parturition (Brod et al., 1982; Lammoglia et al., 1997b; Schaefer et al., 2007; AlZahal et al., 2008)).

Summary

Duration of gestation in cows is an important element of cow reproduction and calf development and performance. Evaluating the effects of elevated ambient temperature on late gestation is important in fall calving herds. Heat stress reduces milk production in cows by diverting blood flow from the udder to the skin surface to reduce the cow's heat load (Collier et al., 1982b). Concentration of cortisol in plasma decreases milk production. Exposure of cows to elevated ambient temperatures increases concentrations of cortisol in plasma therefore reducing milk production (Christison and Johnson, 1972; Flamenbaum et al., 1995). The establishment of milk production before gestation is vital to support for a beef cow to support a calf.

Elevated ambient temperature in the late summer months may cause cows in late gestation to have a shorter gestation and calves with lighter birth weights (Kastner et al., 2004). There is no evidence that low birth weight induced by exposure to elevated ambient temperature has a negative effect on weaning weight (Selk and Buchanan, 1990). Cows calving during times of elevated ambient temperature may undergo heat stress at parturition causing dystocia or death of the calf or cow. Monitoring rumen temperature in late gestation may allow producers to predict the day of parturition and monitor for any calving problems due to heat stress or dystocia. Rumen temperature may also be a valuable tool for detecting estrus in cows. The increase in rumen temperature at estrus is related to ovulation and could be used to improve AI timing and efficacy.

Table 1. Effect of calving month on ambient temperature and duration of gestation of fall calving beef cows over 5 yr

	Gestation, d				Max. Ambient Temp. at calving, ºC	
Year	August		October		August	October
1	279.1 ^{a}	(10)	285.3 ^{b}	(13)	34.4 ^{c}	16.1 ^{d}
2	278.2 ^{a}	(14)	282.4 ^{b}	(9)	32.0 ^{c}	19.8 ^{d}
3	278.0 ^{a}	(8)	281.0 ^{b}	(5)	28.3 ^{c}	19.7 ^{d}
4	278.2 ^{a}	(10)	281.5 ^{b}	(10)	31.8 ^{c}	23.3 ^{d}
5	275.2 ^{a}	(18)	278.8 ^{b}	(4)	36.3 ^{c}	19.7 ^{d}
Mean	277.7 ^{a}		281.9 ^{b}		32.6 ^{c}	20.8 ^{d}

^{a,b} Means within a row without a common superscript differ ($P < 0.05$).
^{c,b} Means within a row without a common superscript differ ($P < 0.01$).
Number of cows in parentheses.

CHAPTER III

EFFECTS OF ELEVATED AMBIENT TEMPERATURE ON DURATION OF GESTATION IN BEEF COWS

ABSTRACT: Angus x Hereford cows (n = 24) were artificially inseminated to calve in August (n = 14) or October (n = 10) to evaluate the effects of ambient temperature on duration of gestation. Cows grazed native grass pasture in Oklahoma and had a body condition score of 6.0 ± 0.5 at parturition. Commencing 2 wk prior to the expected calving date, blood samples were taken from the coccygeal vein every 2 to 3 d until 2 d post partum. Concentrations of progesterone and cortisol were quantified by radioimmunoassay (RIA). Cows that calved in August had shorter gestations (275.2 ± 1.3 d, n = 14, $P = 0.07$) compared with cows that calved in October (278.8 ± 1.4 d, n = 10). Maximum daily ambient temperature during the last 8 d of gestation was greater for August calving cows (36.3 ± 4.5 °C, $P < 0.001$) compared with October cows (25.2 °C ± 7.0). Plasma concentrations of progesterone and cortisol were quantified by RIA. Concentrations of progesterone in plasma during the last 8 d of gestation were not influenced by month of calving. Concentrations of cortisol in plasma during the last 4 d of gestation were greater in cows that calved in August (12.5 ± 0.9 ng/mL, $P < 0.05$) compared with cows that calved in October (9.5 ± 1.0 ng/ml). Shorter gestation in beef cows exposed to elevated ambient temperature was associated with greater concentrations of cortisol in plasma during the last 4 d of gestation.

Key words: Fall calving, beef cows, duration of gestation, heat stress

INTRODUCTION

Duration of gestation for fall calving cows was shorter ($P < 0.05$) for cows calving in August (278.4 d ± 0.8) compared with October cows (282.5 ± 0.9, (Kastner et al., 2004). Heat stress during late gestation alters maternal and placental endocrine functions (Collier et al., 1982b). Exposure to elevated ambient temperatures increased concentrations of progesterone in plasma of Holstein cows (Collier et al., 1982a). Concentrations of cortisol in plasma of cows increases with exposure to elevated ambient temperatures but will decrease as the animal becomes acclimated to the increase temperatures (Christison and Johnson, 1972). The increase in cortisol and decrease in progesterone at the time of parturition may be altered due to the exposure of cows to elevated ambient temperature (Collier et al., 1982b). Objectives of this experiment were to evaluate the influence of exposure of cows to elevated ambient temperatures on duration of gestation and maternal plasma concentrations of progesterone and cortisol.

MATERIALS AND METHODS

Animals and treatments

Angus x Hereford cows (n = 24) 4 to 8 yr of age were stratified by age and bred to calve in either August (n = 14) or October (n = 10). August calving cows were AI on November 11 and October calving cows were AI on January 5. Cows were injected with gonadotropin-releasing hormone (GnRH, 86 ug FerTagyl, Intervet Inc) on d 0 and a CIDR® (1.38 g of progesterone, Pfizer Animal Health) was inserted intravaginally. On d 7 the CIDR® was removed and cows were treated with prostaglandin ($PGF_{2\alpha}$, Lutalyse® 25 mg, Pfizer Animal Health). An injection of GnRH was given on d 9 and cows were AI to one of two Angus bulls with an equal number in each group. Cows grazed native range pasture and were given a 38% CP supplement to maintain a BCS of ≥ 4.5 during the winter. Birth weight of calves was recorded and bull calves were castrated by banding within 1 d.

Plasma Samples

Two weeks prior to the expected calving date, blood samples were obtained by puncture of the tail vein every 2 to 3 d until 2 d after calving. Blood samples were obtained in 10 mL tubes containing EDTA. Samples were kept at 4 °C and centrifuged (1,500 x g for 20 min) within 2 h. Plasma was decanted and samples were stored at -20 °C until analyses.

Hormone assays

Concentrations of plasma progesterone were quantified by radioimmunoassay (Coat-a-count progesterone kit, Siemens medical solutions diagnostics., Los Angeles, CA;(Vizcarra et al., 1997). Concentrations of plasma cortisol was quantified using a RIA (Coat-a-count cortisol kit, Siemens medical solutions diagnostics., Los Angeles, CA). Plasma samples were assayed at 200, 100, and 50 μL for 3 different samples and concentrations of cortisol were paralleled to the standard curve.

Ambient temperature measurements

Ambient temperatures were obtained from the mesonet (Mesonet, 2007) for the Marena site, located 1.6 km south of the pasture where cows calved. Maximum and minimum temperatures for the location were recorded.

Statistical analyses

The effect of temperature on duration of gestation and birth weight of calves were analyzed as a randomized design using PROC MIXED in SAS (SAS inst., Inc., Cary, NC) with month as a fixed effect. Concentrations of progesterone and cortisol in plasma across days of gestation and days before parturition were analyzed with the PROC MIXED for a randomized design with repeated measures over the same experimental unit and included month as a fixed effect and cow was repeated within month. Duration of gestation was calculated (PROC MIXED) for all cows and the effect of month on calving was evaluated. Calf birth weights were analyzed using PROC MIXED in SAS with month and sex included in the model and lsmeans were compared.

RESULTS

Cows that calved in August had a shorter gestation (275.2 ± 1.3 d, P = 0.07) compared with cows that calved in October (278.8 ± 1.4 d; table 2). Average maximum ambient temperature for the last 14 d of gestation was greater for August calving cows (36.3 ± 4.5 °C, P < 0.001) compared with October calving cows (25.2 ± 7.0 °C). Birth weights for August calves (36.7 ± 1.1 kg) were similar (P = 0.87) to October calves (37.0 ± 1.3 kg; table 2). August cows had 10 bulls and 4 heifers and October cows had 6 bulls and 4 heifers. August heifer had a shorter gestation (271.1 ± 1.4 d, P < 0.01) than October heifers (280.5 ± 2.1 d), but length of gestation was not different (P = 0.40) for cows with bull calves in August (278.6 ± 1.4 d) and October (277.0 ± 1.8 d). Heifer calves weighed less (34.1 ± 1.5 kg, P = 0.005) at birth compared with bull calves (39.7 ± 1.0) at birth.

Concentration of progesterone in plasma for cows from 10 to 1 d before parturition were similar by day (P = 0.54) for August and October calving cows (figure 1). Concentration of progesterone in plasma of all cows decreased (P < 0.001) from 10 d (5.5 ± 0.6 ng/mL) before parturition to 1 d (1.8 ± 0.4 ng/mL) before parturition. Average concentration of progesterone from 10 to 1 d before parturition tended to be greater in August cows (4.9 ± 0.3 ng/mL, P = 0.14) compared with October cows (4.2 ± 0.3 ng/mL). Cows with bulls calves (4.3 ± 0.3 ng/mL, P = 0.07) had a greater concentration of progesterone in plasma from -4 to -1 d before parturition compared with cows with heifer calves (3.2 ± 0.40) in August and October. Concentration of progesterone in plasma of cows were similar (P = 0.66) during d 265 to 280 of gestation (figure 2). Concentration of progesterone decreased (P = 0.02) from 265 d (6.1 ± 1.9 ng/mL) of gestation to 280 d (2.8 ± 1.0 ng/mL) of gestation in August and October cows. The decrease in concentration of progesterone in plasma was similar (P = 0.70) for August and October cows from 265 to 280 d of gestation. Concentration of cortisol in plasma from 1 to 4 d before parturition was greater (P < 0.05) for August cows (12.5 ± 0.9 ng/mL) compared with October cows (9.5 ± 1.0 ng/mL; figure 3). Concentration of cortisol in plasma was similar (P = 0.78) among August and October cows by d from 4 to 1 d before parturition. Concentration of cortisol in plasma from 268 to 280 d were similar (P = 0.84; figure 4) for August and October cows. Concentration of cortisol in plasma of October cows tended to decreased (P = 0.10) more from 268 to 280 d of gestation than August calving cows (figure 4). There changed in concentration of cortisol by d was similar (P = 0.26) between August and October cows.

DISCUSSION

Exposure of cows and ewes to elevated ambient temperatures influences reproductive function. Heat stress during early embryonic development reduces conceptus weight and may increase embryonic mortality (Biggers et al., 1987; Morton et al., 2007). During late gestation, heat stress can cause development of dwarf lambs

(Brown et al., 1977). Seasonal differences in birth weight of calves may be a result of exposure of fall cows to elevated ambient temperatures (Kastner et al., 2004). Birth weights of calves in this study were similar for August and October cows, however there were a greater number of bull calves born in August and this may have influenced the effect of season on duration of gestation and birth weight. Kastner et al., (2004) found that August calves weighed less than October calves. When sheep were exposed to elevated ambient temperature in late gestation, dwarf lambs occured and length of gestation was less (Shelton and Huston, 1968). Heat stress may cause a decrease in fetal muscle protein which may be caused by a decrease in uterine blood flow and alter fetal metabolism (Dreiling et al., 1991). Decreased uterine blood flow due to heat stress may stress the fetus and initiate early parturition however additional research is needed to test this hypothesis.

Availability of nutrients to the fetus in late gestation may not influence fetal functions as much as a deficiency in nutrients in early gestation. Restricted nutrient intake by lambs during the first 30 d of gestation resulted in a shorter gestation, but there was no effect on duration of gestation or birth weight when nutrition was restricted in late gestation (Edwards and McMillen, 2002). Killen et al. (1989) found that nutrition restriction in late gestation had no effect on estrogen or progesterone concentration in cows with a BCS of 5.5 before nutritional restriction. Therefore the change in forage quantity or quality in late summer and fall should not cause hormonal changes in a cow. BCS of cows at calving influences birth weight (Richards et al., 1986). Effect of nutrition was not a cause for shorter duration of gestation in this study because cows were maintained at a BCS $\geq$ 4.5 year round and nutrients were not restricted during gestation.

Fall calving cows in the present study all had single births, were a similar type (Angus x Hereford cross) and were all bred to 1 of 2 Angus bull to exclude effect of breed, number of calves or sire. Cows were multiparus and 4 to 8 yr of age. There is no age effect on duration of gestation for cows between 3 and 10 yr of age (Everett and Magee, 1965; Bourdon and Brinks, 1982). Therefore changes in duration of gestation or hormones in late gestation should be due to month of calving with ambient temperature being the major effect.

Collier et al. (1982b) observed that dairy cows with no shade during the last trimester of gestation had greater concentrations of progesterone in plasma compared with cows housed in shade. In our study, concentrations of progesterone were greater in August calving cows exposed to elevated ambient temperatures during late gestation compared with October cows which calved during moderate temperatures. Concentration of progesterone in plasma start to decrease 7 to 10 d before parturition and are minimal on the day of parturition (Pope et al., 1969; Smith et al., 1973). Concentrations of progesterone in plasma decreased similarly in August and October calving cows from 10 d before until the day of parturition when the lowest concentrations of progesterone in plasma were observed.

Concentrations of cortisol in plasma of cows increase during exposure to elevated temperatures (Christison and Johnson, 1972). Cows calving in August had greater concentrations of cortisol in plasma during the last 4 d of gestation compared with October calving cows. August cows were exposed to greater ambient temperatures during late gestation compared with October cows. The fetus releases cortisol to initiate parturition (Smith et al., 1973). Cortisol causes the maturation of the lungs and digestive tract in the fetus (Trahair et al., 1987; Liggins, 1994). Boos et al. (2000) found that 10-20 % of maternal cortisol crossed the bovine placenta into the fetal circulation. Therefore maternal stress will probably not directly initiate parturition, but it could stimulate the fetus to produce more cortisol or act on the fetal hypothalamus or adrenal and cause early maturation resulting in a shorter gestation. Another possible cause for an early release of cortisol could be an increase in fetal temperature resulting from heat stress increasing maternal body temperature. Monitoring fetal temperature during late gestation would be necessary to test this hypothesis.

The duration and magnitude of heat stress, and the time during gestation when heat stress occurs could influence mechanisms that cause a shorter gestation. Mechanisms that cause shorter gestations have not been studied in beef cows. August cows which were exposed to elevated ambient temperatures had higher concentrations of progesterone -10 to -2 d before gestation indicating a hormonal response to elevated ambient temperature. Cows under short term heat stress have higher concentrations of cortisol for several hours compared with cows under heat stress for long periods of time which cause cows to make adjustments to regulate cortisol and heat load (Christison and Johnson, 1972).

These results indicate that exposure to elevated ambient temperature alter maternal hormones related to parturition. The increased concentrations of progesterone and cortisol in late gestation observed in August cows exposed to elevated ambient temperatures may cause a shorter duration of gestation. The effects of elevated ambient temperatures during gestation and parturition in beef cattle is valuable information for producers with late summer and early fall calving herds. It is important that producers know the expected calving date in case the cow needs assistance during calving. Further research is needed to understand the effects of elevated ambient temperature on rumen temperature in late gestation.

Table 2. Influence of month of calving on duration of gestation and birth weight of calves

	August		October	
	Bull	Heifer	Bull	Heifer
Gestation, d	278.6 ± 1.4[a]	271.8 ± 2.2[b]	277.0 ± 1.8[a]	280.5 ± 2.1[a]
	(10)[e]	(4)	(6)	(4)
BW, kg	39.7 ± 1.3[c]	33.8 ± 2.0[d]	39.8 ± 1.7[c]	34.5 ± 2.0[d]
Temperature, °C[f]	36.6 ± 4.5[a]		25.2 ± 7.0[b]	

[a,b] Means in a row without a common superscript differ ($P < 0.01$)
[c,d] Means in a row without a common superscript differ ($P = 0.005$)
[e]Number of calves
[f] Average maximum temperature for last 14 d of gestation

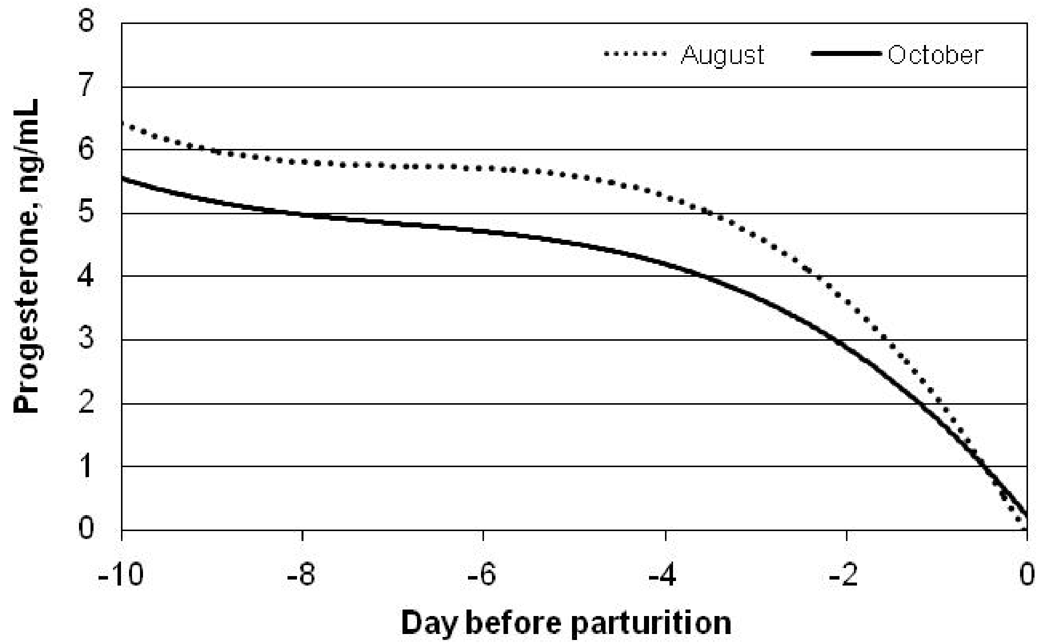

Figure 1. Concentrations of progesterone (ng/mL) in plasma of beef cows from -10 to -1 d before parturition in August and October. The group mean did not differ (P = 0.11) from -10 to the d before parturition. There was a decrease in concentrations of progesterone by day (P < 0.001). Month x day (P = 0.54). SEM = 0.6.

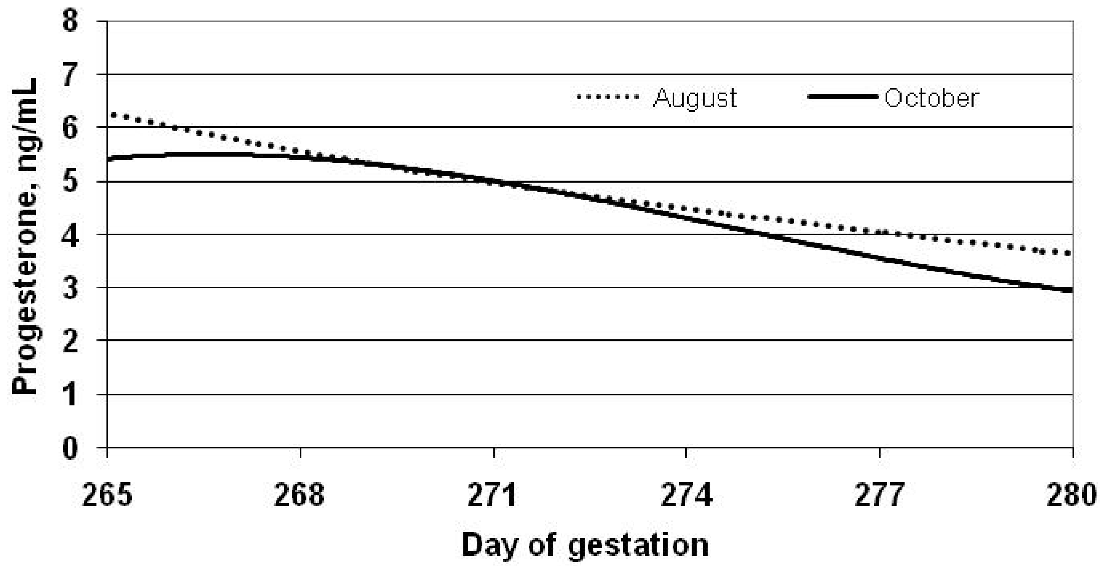

Figure 2. Concentrations of progesterone (ng/mL) in plasma for August and October calving beef cows from 265 to 280 d of gestation. August and October cows had similar concentrations of progesterone in plasma from 265 to 280 d of gestation ($P = 0.66$). Concentration of progesterone decreased ($P = 0.02$) as day of gestation increased. Month x day ($P = 0.70$). SEM = 1.2.

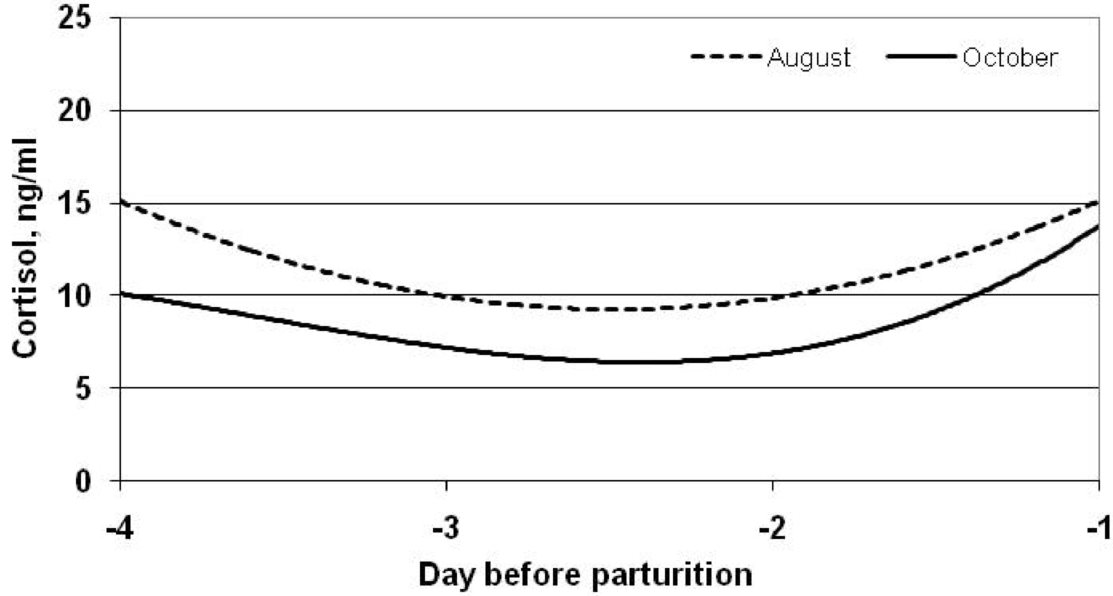

Figure 3. Concentrations of cortisol (ng/mL) in plasma of beef cows -4 to -1 d before parturition in August and October. Concentrations of cortisol were greater (P = 0.04) in August cows compared with October cows from -4 to the d before parturition. Concentrations of cortisol in plasma were effected by day (P = 0.008). Month x day (P = 0.78). SEM = 2.0.

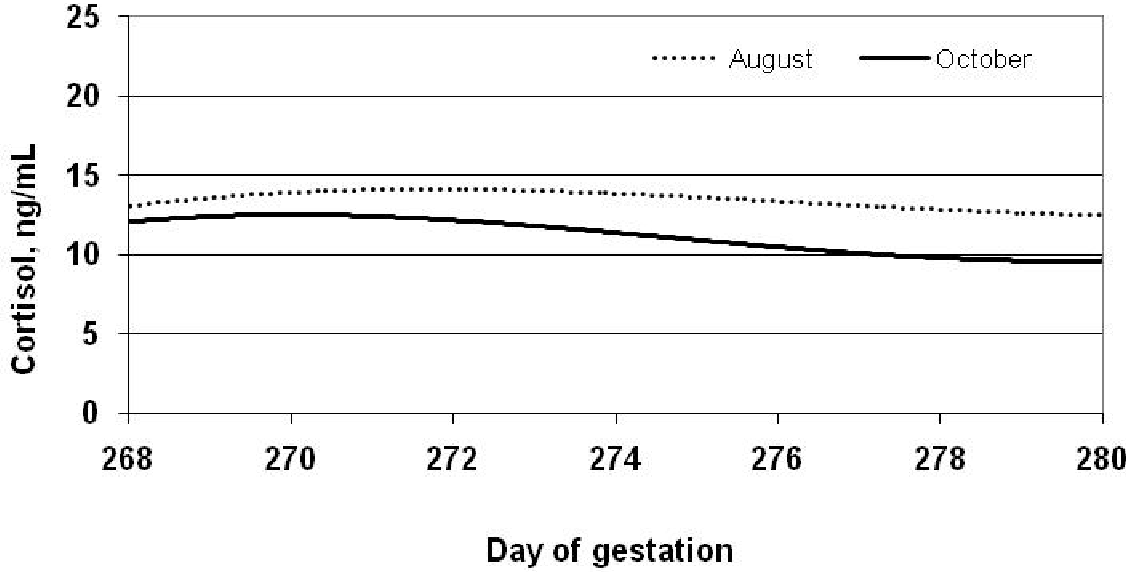

Figure 4. Concentrations of cortisol (ng/mL) in plasma of August and October calving beef cows from 268 to 280 d of gestation. Concentrations of cortisol in plasma was similar (P = 0.84) from 268 to 280 d of gestation for August and October cows. Concentrations of cortisol in plasma did not differ (P = 0.26) from 268 to 280 d of gestation. Month x day (P = 0.10). SEM = 3.5.

CHAPTER IV

RUMEN TEMPERATURE AT PARTURITION AND ESTRUS IN FALL CALVING BEEF COWS.

ABSTRACT: Angus x Hereford cows (n = 27) were artificially inseminated to calve in either mid August, late August, September or October to evaluate the effects of elevated ambient temperature on duration of gestation, rumen temperature at parturition, and rumen temperature at estrus. Temperature boluses (SmartStock, LLC) programmed to transmit temperature every h were place in the rumen at 255 d of gestation. Cows grazed native pastures in Oklahoma and had a body condition score of 6.5 ± 0.4 at calving. Maximum ambient temperatures during the week before the expected calving date were greater for mid August (34.1 ± 2.3 °C) and late August (34.0 ± 2.7 °C, $P < 0.001$) compared with September (29.7 ± 3.5 °C) and October (28.5 ± 2.7 °C) cows. Duration of gestation was shorter for cows in mid August (274.7 ± 5.5 d, $P = 0.05$) compared with October (278.8 ± 3.1 d) cows, but did not differ from late August (277.0 ± 2.5 d, $P = 0.29$) and September (276.2 ± 3.1 d, $P = 0.50$) cows. Rumen temperature during the week before calving was not influenced by month of calving ($P = 0.84$) and averaged 38.8 ± 0.3 °C for all months. Rumen temperature decreased 24 h prior to parturition for cows in all months ($P < 0.01$). Concentrations of cortisol in plasma from -4 to -1 d before parturition was less for late August (6.3 ± 5.7 ng/mL) compared with mid August (10.8 ± 5.9 ng/mL, $P = 0.03$) and October (12.5 ± 4.7 ng/mL, $P = 0.003$)

cows, and similar with September (9.68 ± 1.38, $P = 0.15$) cows. Progesterone concentration in plasma of cows did not differ between months from -7 to -1 d before parturition ($P = 0.83$). Concentration of estradiol in plasma of cows increased ($P = 0.001$) by day of gestation from 268 to 280 d of gestation. Concentration of estradiol in plasma of cows were similar among months ($P = 0.69$) from -7 to -1 d before parturition. Rumen temperature was greater during the first 8 h of estrus (38.7 ± 0.1 °C, $P < 0.001$) compared with 16 to 24 h before (37.95 ± 0.1 °C) and 16 to 24 hours after (37.99 ± 0.1 °C) the onset of estrus.

Concentration of progesterone and estradiol in plasma were not affected by exposure to elevated ambient temperatures during late gestation. Concentration of cortisol in plasma was decreased in late August cows that were exposed to elevated ambient temperature from 260 to 266 d of gestation compared to mid August, September, and October cows. Exposure of beef cows to elevated ambient temperature results in shorter gestations. Rumen temperature in cows decreases ≥ 0.3 °C the d before parturition. Rumen temperature in cows increases ≥ 0.3 °C at the onset of estrus including the 8 h after onset and compared to the same daily h on the d before estrus.

INTRODUCTION

Exposure of cattle to elevated ambient temperatures reduces productivity and reproductive performance. Average gestation of beef cows is 283.6 d, and can be influenced by breed, genetics, number of calves, sex of calf, and environment (Cundiff et al., 1998). Parturition is initiated by the calf; the fetal hypothalamus secretes corticotrophin releasing hormone which causes the pituitary to release corticotrophin, and cortisol is secreted by the adrenal gland (Wagner et al., 1974). Increased concentration of cortisol in the fetus influences the placenta and initiate a cascade of endocrine events in the cow, resulting in reduced progesterone secretion by the CL and/or placenta, increased concentrations of estradiol, estrone and cortisol in plasma, and parturition (Bazer and First, 1983). A decrease in body temperature may occur before parturition and may be used to predict day of parturition in cows (Wrenn et al., 1958; Lammoglia et al., 1997a; Prado-Cooper et al., 2008). An increase in body temperature during the estrous cycle may be associated with estrus in beef cows (Clapper et al., 1990; Rajamahendran and Taylor, 1991b). The objectives of this experiment were to determine the effect of elevated ambient temperature on duration of gestation and maternal concentrations of progesterone, cortisol and estradiol and to evaluate changes in rumen temperature at parturition and estrus.

Materials and Methods

Angus x Hereford cows (n = 27), 4 to 8 yr of age, were stratified by age and randomly assigned to four fall calving groups. Cows were synchronized with an injection of prostaglandin (PGF $_{2\alpha}$, Lutalyse® 25 mg, Pfizer Animal Health). Cows were AI to one of 2 angus bulls to calve in mid August (expected calving date Aug 22, n = 7), late August (expected calving date Aug 29, n = 6), September (expected calving date September 9, n = 6) or October (expected calving date October 17, n = 8). Cows grazed native range pasture and were supplemented with 38% CP during the winter to maintain a BCS > 4.5 ± 0.5 (Wagner et al., 1988). Cows calved with a BCS of 6.0 ± 0.5 and calves were weighed and bulls were castrated within 1 d of birth.

Temperature measurements

Temperature boluses (www.smartstock-usa.com, SmartStock, LLC) were placed in the rumen of cows at 255 d of gestation and temperature was recorded by telemetry. Boluses were programmed to transmit rumen temperature every h which included hourly temperatures for the previous 12 h. Three antennas were placed on the perimeter of the calving pasture (3.2 ha) which relayed the signal to an antenna at the barn. Data were recorded with a computer. Ambient temperatures were recorded by mesonet at the Marena location about 6 km south of the calving pasture (Mesonet, 2007).

Rumen temperatures relative to estrus were averaged for 8 h periods starting at the onset of estrus determined by Heat watch®. Rumen temperature during the first 8 h of estrus was compared with rumen temperature 24 to 32 h before and 24 to 32 h after the onset estrus to calculate changes in rumen temperature at estrus. Cows with rumen boluses were monitored from 2 d prior to expected estrus to 2 d after AI. Consumption of cold water causes a decrease in rumen temperature to < 37.72 °C (unpublished data OSU), and temperatures < 37.72 °C were excluded from analyses.

Plasma Samples

Blood samples were obtained every second day from 255 to 265 d of gestation, and then daily until parturition. Samples were obtained by puncture of the coccygeal vein into tubes containing EDTA and immediately put on ice. Samples were centrifuged 2500 x g within 2 h and plasma was decanted. Plasma was stored at -20 °C until analyzed.

Hormone assays

Concentration of progesterone in plasma was quantified by RIA (Coat-a-count progesterone kit, Siemens Medical Solutions Diagnostics., Los Angeles, CA). Inter – and intrassay coefficients of variation were 4.7 % and 7.5 %, respectively, for 2 samples in each of 4 assays. Interassay coefficient of variation is the difference in a sample quantified in each assay. Intraassay coefficient of variation is the difference in a sample quantified twice within an assay. Each assay included equal numbers of cows from each month with all samples for a cow in the same assay. Concentrations of cortisol in plasma were quantified using a solid phase RIA (Coat-a-count cortisol kit, Siemens Medical Solutions Diagnostics). Samples of cortisol were paralleled to the standard curve when 25, 50, 100, and 200 μL of bovine plasma were analyzed. Inter- and intrassay coefficients of variation were 15.9% and 14.1 %, respectively, for 2 samples in each of 4 assays.

Estradiol MAIA assay kit (Biodata SpA, Montecelio, Italy) was used to determine concentrations of estadiol in cows (Vizcarra et al., 1997). Estradiol was extracted from 200 μL of plasma with 2 mL of ethyl acetate (HPLC-UV Grade, Pharmco Products Inc, Brookfield, CT), in capped 12 x 75 mm tubes by vortexing for 2 min, and then allowing the sample to separate for 10 min. One mL of the solute was transferred to a 12 x 75 mm tube and air dried on a heating block at 37°C. Two hundred mL of phosphate buffer (0.01 M, pH 7.0) was used to dissolve each sample. The first antibody supplied in the assay kit was diluted 1:2 in phosphate buffer and the assay kit protocol was used. Estradiol was extracted from 100 and 200 μL of bovine plasma and concentrations were parallel to the standard curve. Inter- and intraassay coefficients of variation were 9.1 and 29.2%, respectively, for 2 samples in each of 4 assays.

Estrus detection

Cows were synchronized with an injection of prostaglandin ($PGF_{2\alpha}$, Lutalyse 25 mg, Pfizer Animal Health) 84.6 ± 21.7 d after calving and AI on either Dec 2 or Dec 13. Heat Watch® (Cowchips LLC, Denver, CO) was used to monitor onset of estrus. Onset of estrus was defined as the first two mounts within a 4 h period. The end of estrus was defined as the last mount received, with a mount 4 h before and no mounts during the next 12 h (White et al., 2002). A pressure sensor and radio transmitter were placed in a nylon patch which was attached on the tailhead with adhesive. Cows with patches were kept in 3.2 ha pasture within transmission range of the main antenna at the barn so data could be downloaded and stored on a computer. Cows were AI 12 h after the onset of estrus. Boluses were programmed to transmit rumen temperature every h which included hourly temperatures for the previous 12 h.

Statistical analyses

The effects of calving month on maximum ambient temperature, duration of gestation, rumen temperature, and birth weight were analyzed as a randomized design using PROC MIXED procedure of SAS (SAS inst., Inc., Cary, NC) with month in the model as a fixed effect. Concentrations of progesterone, estradiol, and cortisol in plasma across time were analyzed using the PROC MIXED procedure of SAS for a randomized design with repeated measures over the same experimental unit (cow) and included month of calving as a fixed effect. Concentrations of estradiol in plasma were transformed to the natural log (x +1) for analysis because of heterogeneity of variation (Steel et al., 1997). The relationship between progesterone and estradiol in plasma were analyzed by a partial correlation correcting for day using PROC CORR of SAS. The 72 h before parturition were divided into three 24 h periods to compare changes in rumen temperature, 0 (h of birth) to 24 h, 24.5 to 48 h, and 48.5 to 72 h before parturition. Ambient temperature, day before parturition, and group were covariables using PROC MIXED in SAS and cow was repeated within group. A simple correlation was used to determine relationships between rumen temperature and average ambient temperature on the same day the week before parturition PROC CORR in SAS. Rumen temperature at estrus was averaged for first 8 h periods relative to the onset of estrus (h = 0) as determined by Heat Watch®. Eight h periods during 16 to 24 h before and 24 to 32 h after onset of estrus were compared to the 8 h after onset of estrus using PROC MIXED. Maximum rumen temperature was determined for each cow during estrus and compared with the rumen temperature at onset of estrus to determine the relationship between the increase in rumen temperature and onset of estrus. Cow was repeated in the model. Chi-square analysis (SAS) was used to determine the rate of false negatives and false positives for change in rumen temperature ≥ 0.3 °C at parturition and estrus. Changes in rumen temperature ≥ 0.3 °C during a period of time other than parturition or estrus were identified as false positives. Changes in rumen temperature ≤ 0.3 at parturition or estrus were false negatives.

RESULTS

Duration of gestation was shorter for cows calving in mid August (274.7 ± 1.4 d, P = 0.05) compared with cows that calved in October (278.8 ± 1.3 d), but did not differ from late August (277.0 ± 1.5 d) or September (276.2 ± 1.5 d, Table 3). There was no effect of sire on month of calving or duration of gestation (P = 0.23). Maximum mean ambient temperature during the 7 d before parturition was greater for mid August (34.1 ±

2 °C) and late August (34.0 ± 3 °C, $P < 0.01$) compared with September (29.7 ± 4 °C) and October (28.5 ± 3 °C; Table 3). Birth weight was similar ($P = 0.57$) for calves born in mid August (37.9 ± 2.2 kg), late August (37.4 ± 1.7), September (36.0 ± 1.8) and October (39.3 ± 1.4, Table 4). Sex of calf did not have an effect ($P = 0.19$) on birth weight. Bull calves had a birth weight of 38.9 ± 1.5 kg and heifer calves had a birth weight of 36.4 ± 1.0 kg (Table 4).

Hormone analyses

Concentrations of progesterone in plasma were not influenced ($P = 0.83$) by calving groups during -7 to -1 d before parturition (figure 5). Concentrations of progesterone in plasma were less ($P < 0.001$) on the day before parturition compared with the previous 6 d. Concentrations of progesterone in plasma were similar among groups from 272 to 277 d of gestation ($P = 0.74$; figure 6). There was a tendency for a group x day effect on concentrations of cortisol in plasma during -4 to -1 d before parturition ($P = 0.07$; figure 6). Late August cows tended to have less cortisol (8.4 ± 5.1 ng/mL, $P = 0.09$) in plasma the week before parturition compared with mid August (12.2 ± 5.0 ng/mL), September (11.5 ± 3.4 ng/mL) and October cows (13.0 ± 4.9 ng/mL, figure 7). Concentrations of cortisol in plasma did not differ among groups from 272 to 277 d of gestation ($P = 0.75$) and there was no group x day of gestation effect ($P = 0.64$; figure 8). Estradiol in plasma was similar among groups ($P = 0.69$) during d -7 to -1 before parturition. Estradiol increased from 6 d (71.8 ± 18.3 pg/mL, $P < 0.001$) before to the 1 d (108.6 ± 18.2 pg/mL, figure 9) before parturition. Concentration of estradiol in plasma increased ($P = 0.001$) by day of gestation from 268 (63.6 ± 22.1 pg/mL) to 280 (127.0 ± 22.2 pg/mL) d of gestation (figure 10). There was no group x day of gestation effect on concentration of estradiol in plasma (P = 0.43). There was a partial negative correlation (r = - 0.31) between concentrations of progesterone in plasma and concentrations of estradiol in plasma.

Rumen temperature at parturition

Calving group did not influence rumen temperature 3 d before parturition (P = 0.22). Rumen temperature decreased 0.3 °C (P < 0.001) in cows in all groups the day before parturition compared with 2 and 3 d before parturition (figure 11). At 2 d before parturition mid August cows had a greater rumen temperature (38.9 ± 0.2, P = 0.03) compared with October (38.4 ± 0.1) and late August (38.7 ± 0.1, P = 0.28) cows. Rumen temperature of September (38.8 ± 0.1, P = 0.48) cows was not different from August or October cows. Rumen temperature of mid August cows changed the least (P = 0.06) from the 2 d before parturition (38.9 ± 0.2 °C) to the day before parturition (38.6 ± 0.1; figure 12). Average daily maximum ambient temperature during 255 to 280 d of gestation was greater in mid August (34.1 ± 2.0 ºC, P < 0.01) and late August (34.0 ± 3.0 ºC) compared with September (29.7 ± 4.0 ºC) and October (28.5 ± 3 ºC, figure 13). Mean daily maximum ambient temperature the week before parturition was not correlated (P = 0.13) with rumen temperature. Rumen temperature was less (38.48 ± 0.06 °C; P = 0.002) the day before parturition compared with -24.5 to 48 h (38.72 ± 0.07°C) and 48.5 to 72 h (38.80 ± 0.07°C) before parturition. Mid August cows had a greater rumen temperature (38.94 ± 0.10, P = 0.04) during the total 72 hr period compared with late August (38.59 ± 0.09 °C), September (38.59 ± 0.09 °C) and October (38.55 ± 0.09 °C, figure 13) cows. All calving groups had a similar (P = 0.22) decrease (P < 0.001) in rumen temperatur from 3 d before to the d of parturition that was not affected by ambient temperature (P = 0.50). A decrease in rumen temperature ≥ 0.3 from d -2 to -1 before parturition occurred in 100% of mid August calving cows. Using this same criterion parturition could have been predicted for 66% of September calving cows and 40% of late August and October cows. October cows had a decrease of 0.3 °C from 3 d before parturition to 2 d before parturition. This criterion held true in 50% of the mid August cows, 33% of the September cows and 16% of the late August cows. Rumen temperature decreased ≥ 0.3 °C in 7% of cows -4 to -10 d before parturition. A change in rumen temperature ≤ 0.3 °C was observed in 38 % of cows from 2 d before to the d before parturition.

Rumen temperature at estrus

Rumen temperature during the first 8 h after onset of estrus was greater (38.7 ± 0.1 °C, P < 0.001) compared with the same 8 h (37.9 ± 0.1 °C) on the day before onset of estrus and the same 8 h on the day after onset of estrus (37.9 ± 0.1 °C; figure 14). Rumen temperature was similar (P = 0.88) on the day before and on the day after estrus was detected. Ambient temperature did not affect (P = 0.83) the change in rumen temperature at estrus. Estrus was detected by an increase of rumen temperature ≥ 0.3 °C in 83.3% of the cows (Table 5). An increase in rumen temperature during estrus did not occur in 6.0% of cows. An increase in rumen temperature ≥ 0.3 ºC when cows were not estrus was observed in 11.1% of cows. Maximum rumen temperatures during estrus occurred within 3 h before or after the onset of estrus (figure 15).

DISCUSSION

Mid August calving cows had a shorter gestation compared with October cows, while late August and September cows were intermediate in gestation compared with mid

August and October. Kastner et al., (2004) found that cows calving in August had a shorter duration of gestation and calves weighed less compared with cows that calved in October in Oklahoma. Selk et al., (1990) observed that fall calves weighed less at birth compared with spring calves but duration of gestation was similar for spring and fall calving cows. Cows in Kastner's study calved in the month of August and cows in Selk's study calved in September and October over a six week period. Cows that calved in August were exposed to increased ambient temperatures during late gestation while October calving cows experienced moderate ambient temperatures during late gestation (Mesonet, 2007). Feed intake and feed efficiency decrease during heat stress (Mader and Davis, 2004). Heat stress can cause a decrease in birth weight (Collier et al., 1982b). Decreased feed intake during times of heat stress may be the cause of decreased birth weights in fall calves. Mid August cows were exposed to maximum ambient temperatures > 35 ^{o}C from 269 to 275 d of gestation and had a shorter gestation than October calving cows which were not exposed to maximum ambient temperatures > 35 C in late gestation. Late August cows were exposed to these same ambient temperatures as mid August calving cows, earlier in gestation, from 260 to 266 d and had a duration of gestation that was intermediate between Mid August and October cows. The time during late gestation when elevated ambient temperature can shorten gestation is after 265 d of gestation based on these results. The duration of exposure to elevated temperatures to cause a decrease in duration of gestation may be as much as a week depending on how extreme temperatures are during the late gestation.

Progesterone, estradiol, and cortisol were similar for all groups. This indicates that a hormonal change in the cow due to exposure to elevated ambient temperatures is not the cause for shorter gestation. Parturition is initiated by the fetus with the release of ACTH from the pituitary. Cortisol is then produced and secreted from the fetal adrenal gland. Cortisol acts on the placenta and crosses into the maternal system where a cascade of hormonal events begins (Smith et al., 1973; Wagner et al., 1974). Concentrations of cortisol in plasma of the cow increased the day of parturition (Smith et al., 1973; Hudson et al., 1976). An increase in concentration of cortisol was not observed in the present study because cows were only sampled once a day. The increase in cortisol in the plasma of the cow at parturition is increased for 12 hr due to the act of labor and then concentration of cortisol in the plasma return to basal concentrations (Hudson et al., 1976). Concentrations of cortisol are increased due to stress (Christison and Johnson, 1972). Exposure to elevated ambient temperatures could potentially cause an increase of cortisol in the fetus in addition to the cow. Cows that calved in late August have less cortisol in plasma from -7 to -1 d before parturition compared with the mid August, September and October cows. Late August cows were exposed to ambient temperatures ≥ 35 °C from d 260 to 266 the cows had time become accustom to the heat stress and concentrations in cortisol were then lower during the following days. This is similar to results in a study by Christison et al., (1972) which demonstrated that cows exposed to elevated ambient temperature for a short time become accustomed to the environment and have lower concentrations in cortisol in plasma than cows exposed to the same environmental conditions for 7 to 10 wks. Concentrations of progesterone in plasma can also be increased by a stressful environment during gestation (Willard et al., 2005). Cows in the present study did not have elevated concentrations of progesterone due to exposure to elevated ambient temperatures. There was a decrease in concentration of progesterone in plasma from -7 to -1 d before parturition. Concentrations of progesterone in plasma decrease at parturition due to decreased production by the placenta and CL (Smith et al., 1973; Wagner et al., 1974). Concentrations of estradiol in plasma increased at parturition in all fall calving cows from -7 to -1 d before parturition. Estrogens are produced by the placenta in response to cortisol at parturition (Smith et al., 1973). The hormonal changes at parturition were similar for all fall calving groups regardless of duration of gestation or exposure to elevated ambient temperatures.

Rumen temperature was greater in mid August cows on the day before parturition compared with the late August, September and October cows. Mid August cows were exposed to ambient temperatures above 35 °C from 269 to 275 d of gestation which resulted in a shorter gestation for the cows.   The change in rumen temperature at parturition could be used to predict time of parturition. A decrease of rumen temperature ≥ 0.3 °C could have been used to successfully predicted in 57.9% of fall calving cows. A decrease in body temperature at calving has been observed (Wrenn et al., 1958; Sawada et al., 1988; Lammoglia et al., 1997a; Prado-Cooper et al., 2008). The decrease in body temperature may be due to the decrease in progesterone relative to parturition (Wrenn et al., 1958). Lammoglia et al., (1997a) did not find a relationship between sex hormones and the decrease in body temperature at parturition when measuring temperature inside flank of the cow. Temperature must be measured frequently to get an accurate measurement for a cow throughout the day. Prado- Cooper et al., (2008) measured rumen temperature every 15 min near the time of parturition and observed a decrease in rumen temperature ≥ 0.3 °C the day before parturition in spring calving cows. Rumen temperature decreased at parturition in all fall calving groups and could be used to predict the day of parturition.

When estrus was synchronized in early December, cows had an increase in rumen temperature ≥ 0.3 °C for an average of 8 h at the onset of estrus. Heat Watch ® was used to determine the onset of estrus so that all mounts were recorded throughout the trial period without the need for human observation. Clapper et al. (1990) found a similar increase in vaginal temperature by taking temperature measurements every hour vaginal temperature was elevated for approximately 8 h. In the current study rumen temperature at estrus was averaged for 8 h periods and compared with the same daily h 24 h before and after the onset of estrus. This model was able to predict onset of estrus for 83.3% of cows. Rumen temperatures at estrus averaged over a 16 h period and compared with a 16 h period the previous day predictability decreased to 38.2%. Similarly if a 16 h period starting 8 h before onset of estrus and ending 8 h after estrus was compared to the same daily h on the day before and after estrus predictability decreased to 42.1%. We used an estrus prediction model with 8 h periods. Duration of estrus in cows is about 16 h and ovulation occurs about 16 h after estrus (White et al., 2002b). Rumen temperature was elevated for 7.5 h in this study. Redden et al. (1993b) found that vaginal temperature was elevated for 6.8 ± 4.6 h at estrus. Clapper et al. (1990) determined that the elevation in vaginal temperature at estrus was 8.14 ± 3.5 h. The maximum temperature observed during estrus was determined to be within 4 h of onset of estrus (Clapper et al., 1990). Rectal and vaginal maximum temperatures are related to onset of estrus but not ovulation (Rajamahendran and Taylor, 1991b). Cows that ovulated without estrus also had an increase in body temperature (Zartman and Dealba, 1982b). Estrus is associated with an increase in physical activity for cows in estrus and other cows mounting estrous cows, and this could cause false positives (Pennington et al., 1986). The increase in body temperature due to participating in estrous activity is a short term increase and is not as elevated or prolonged as cows in estrus (Walton and King, 1986b). False positives should be greatly reduced by averaging periods of time during the day and comparing them to the same daily hours on the previous day. The physical activity should not increase the period of time enough to significantly increase body temperature and simulate estrus, but a small percentage of false positive may persist. Rumen boluses provide a non-invasive, frequent measurement of core body temperature. The SmartStock bolus system could be programmed to analyze temperature data in periods of time and compare period between days giving an accurate prediction for day of parturition and onset of estrus. In addition animal health, water and feed intake could be monitored to provide a complete portrait of bovine reproduction and production.

Table 3. Effect of ambient temperature the last two weeks of gestation on duration of gestation in fall calving beef cows

Calving Month	Gestation, d	Max Ambient Temp, ºC
Mid August	274.7 ± 1.4^{a}	34.1 ± 0.6^{c}
Late August	277.0 ± 1.5^{ab}	34.0 ± 0.6^{c}
September	276.2 ± 1.5^{ab}	29.7 ± 0.6^{d}
October	278.8 ± 1.3^{b}	28.5 ± 0.6^{d}

^{a,b} Means without a common superscript differ (P < 0.05).

^{c,b} Means without a common superscript differ (P < 0.01).

Table 4. Birth weight and sex of calves born in mid August, late August, September and October

Month	Birth weight[a]	Bulls[b]	Heifers[b]
Mid August	83.4 ± 4.9	1	6
Late August	82.3 ± 3.7	3	3
September	79.3 ± 3.9	2	4
October	86.4 ± 3.2	4	4

[a]Birth weight was similar for all months (P = 0.57).
[b] Birth weight was similar (P = 0.19) for bull and heifer calves.
[a,b]Month x sex (P = 0.22)

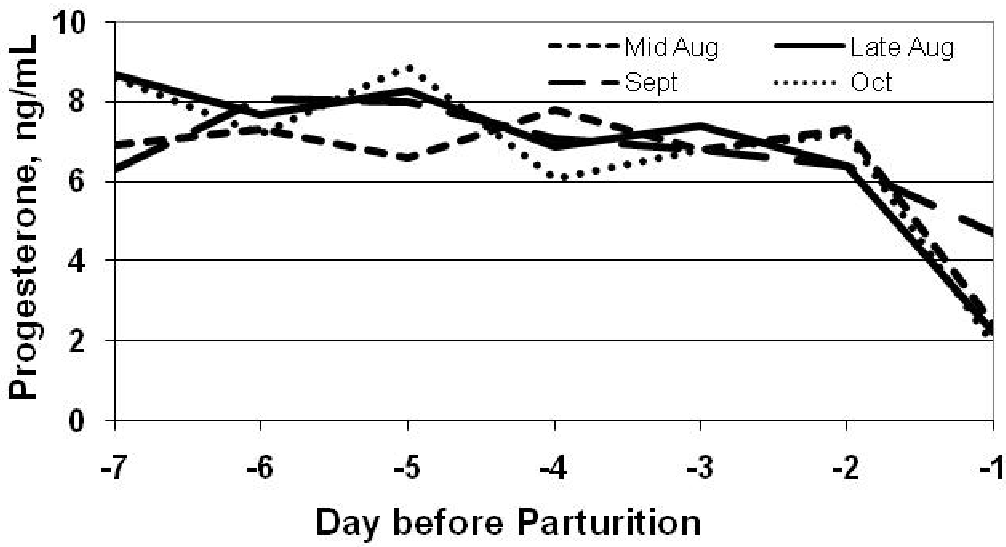

Figure 5. Concentration of progesterone (ng/mL) in plasma -7 to -1 d before parturition in fall calving beef cows from mid August, late August, September and October. Concentration of progesterone in plasma was similar (P = 0.83) for all months from -7 to the day before calving. There was a decrease (P = 0.01) in progesterone from -7 to the d before calving. Month x day (P = 0.19). SEM = 0.9.

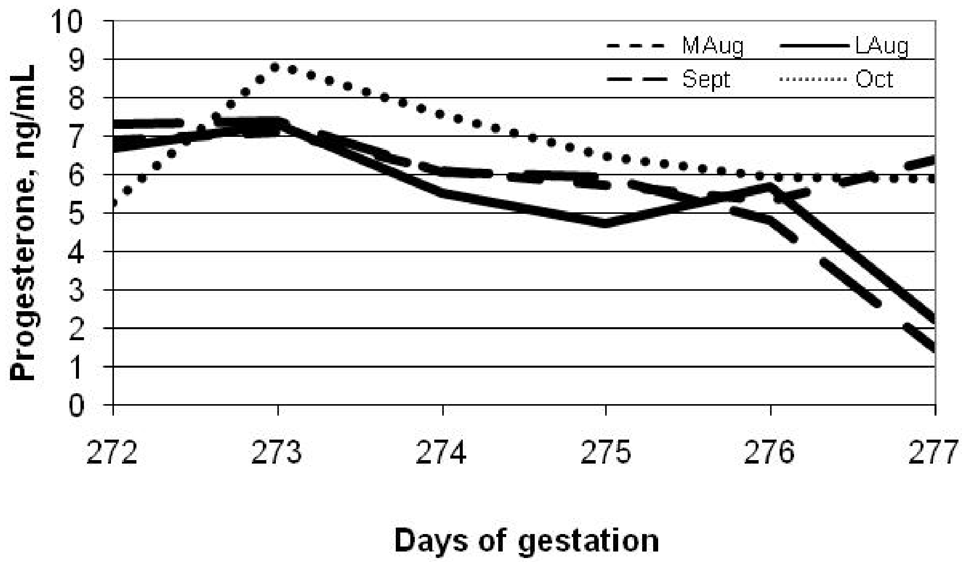

Figure 6. Concentration of progesterone (ng/mL) in plasma during d 272 to 277 of gestation for cows calving in mid August, late August, September, and October. Concentration of progesterone in plasma was similar (P = 0.73) for all groups from 272 to 277 d of gestation. Month x day (P = 0.56). SEM = 1.5.

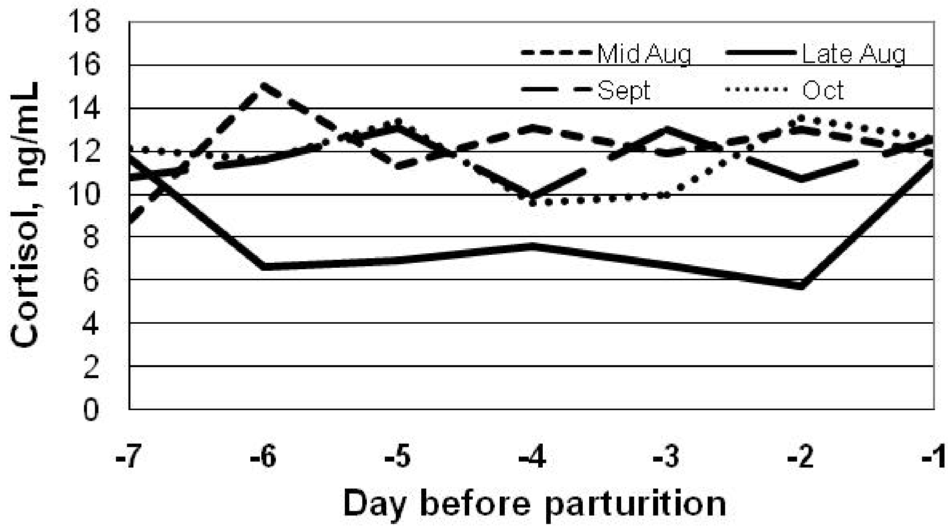

Figure 7. Concentrations of cortisol (ng/mL) in plasma from -7 to -1 d before parturition for cows calving in mid August, late August, September and October. Concentrations of cortisol in plasma tended to be less (P = 0.07) in late August cows compared with mid August, September, and October cows. Concentrations of cortisol in plasma did not differ (P = 0.67) from -7 to the d before parturition for all months. Month x day (P = 0.27). SEM = 2.1.

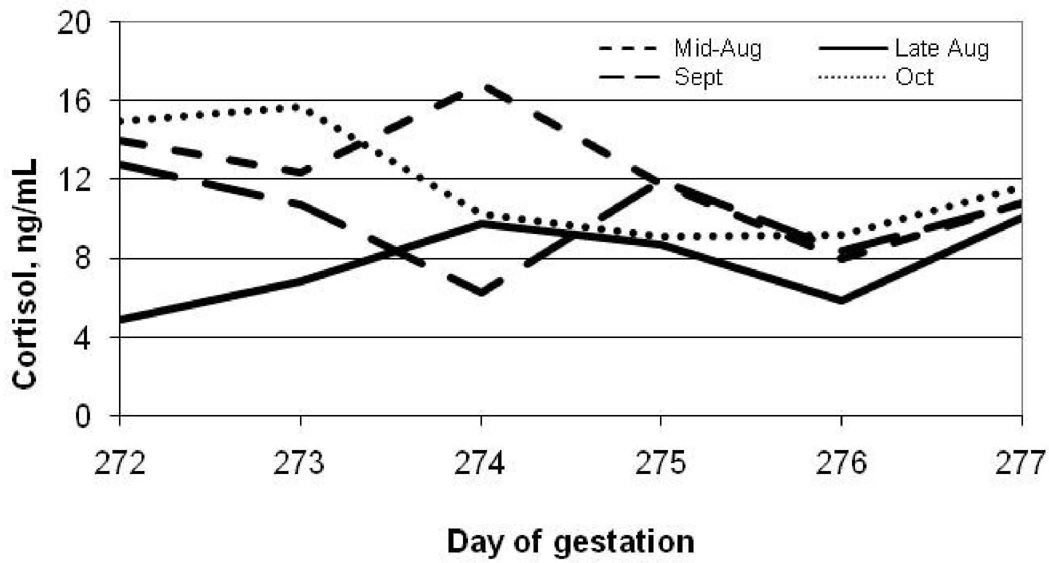

Figure 8. Concentrations of cortisol (ng/mL) in plasma during 272 to 277 d of gestation for cows calving in mid August, late August, September, and October. Concentrations of cortisol tended to be less ($P = 0.06$) in late August cows compared with mid August, September, and October cows. There was no effect ($P = 0.50$) of day of concentrations of cortisol from 272 to 277 d of gestation. Month x day ($P = 0.64$). SEM = 2.9.

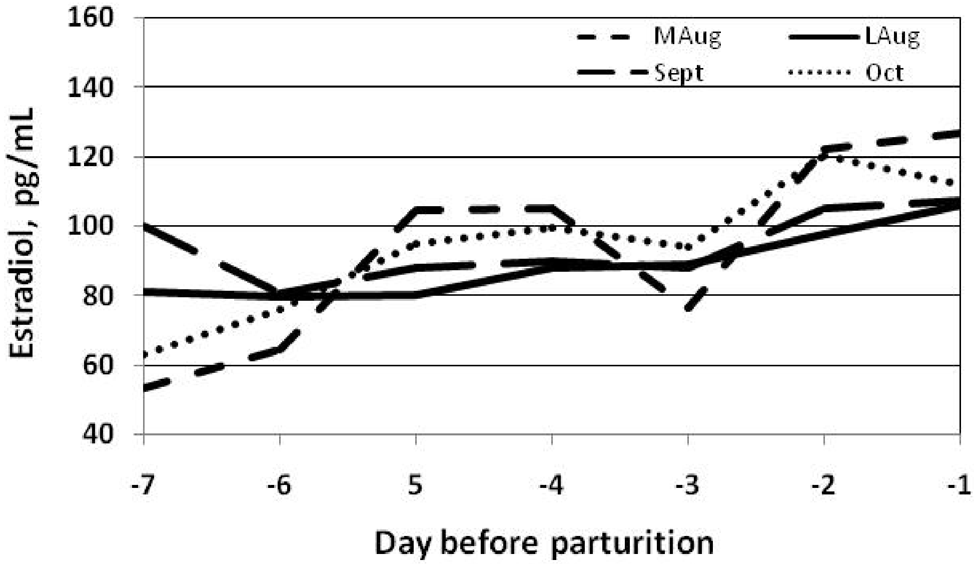

Figure 9. Concentrations of estradiol (pg/mL) in plasma during -7 to -1 d before parturition for cows calving in mid August, late August, September, and October. Concentrations of estradiol in plasma were similar (P = 0.47) for all months from -7 to the d before calving. Concentrations of estradiol in plasma increased (P = 0.001) from -7 to the d before calving. Month x day (P = 0.25). SEM = 22.5.

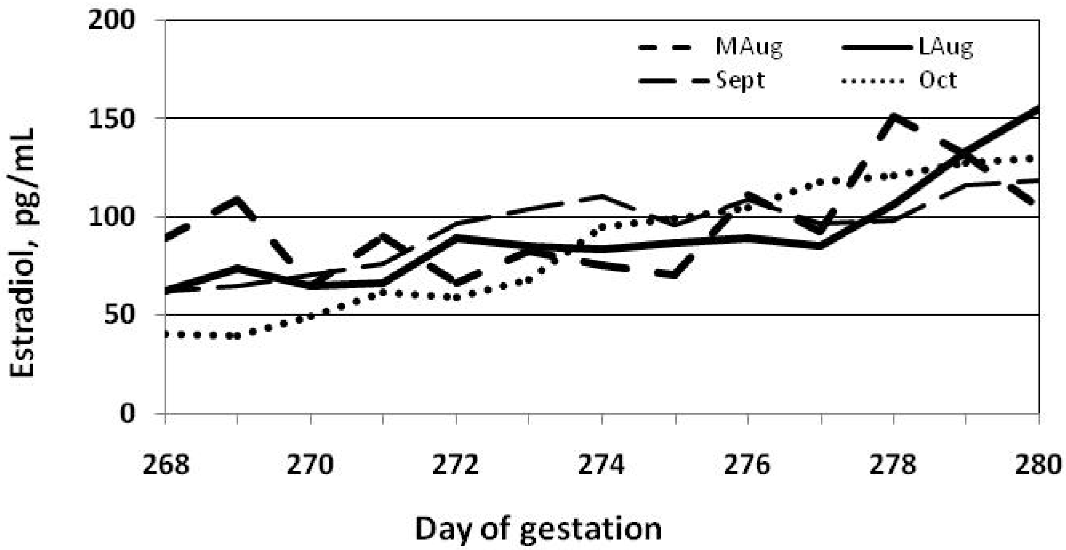

Figure 10. Concentrataions of estadiol (pg/mL) in plasma during 268 to 280 d of gestation in cows calving in mid August, late August, September, and October. Concentrations of estradiol in plasma were similar (P = 0.95) in all months from 268 to 280 d of gestation. There was an increase (P = 0.001) in concentrations of estradiol in plasma from 268 to 280 d of gestation. Month x day (P = 0.47). SEM = 28.0.

Figure 11. Rumen temperature for fall calving beef cows -3 to -1 d before parturition. Rumen temperature decreased ($P < 0.001$) the d before parturition compared with -3 and -2 d before calving. SEM = 0.1.

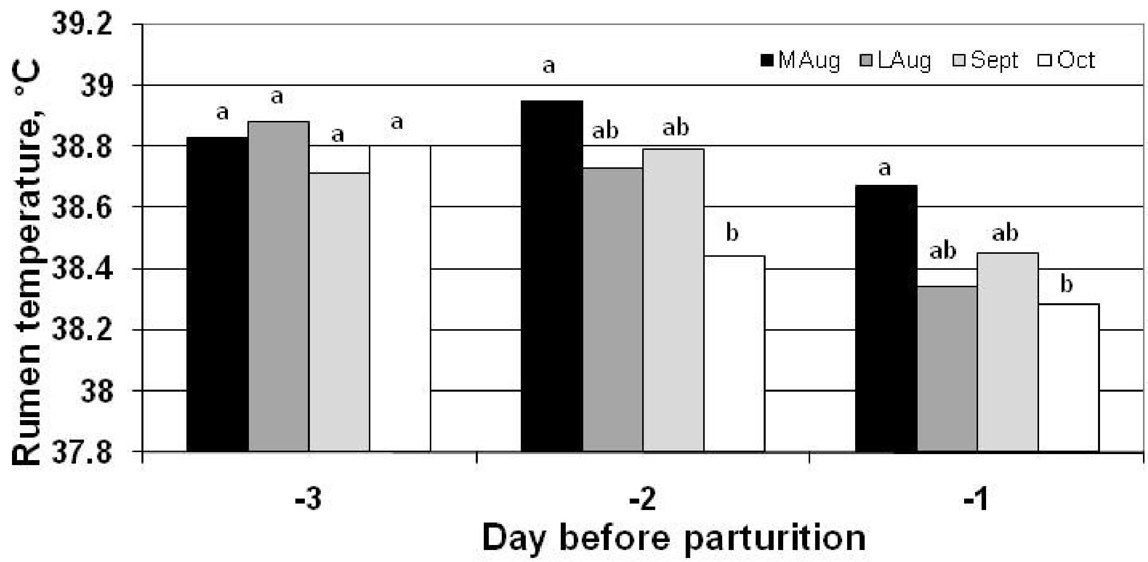

Figure 12. Rumen temperature -3 to -1 d before parturition for mid August, late August, September and October calving beef cows. Rumen temperature decreased ($P < 0.001$) by d from -3 to the d before parturition in all months. A, b Rumen temperature was greater ($P = 0.01$) in mid August cows on 1 and 2 d before parturition compared to October cows. Rumen temperature for late August and September cows was intermediate. Month x day ($P = 0.51$). SEM = 0.1.

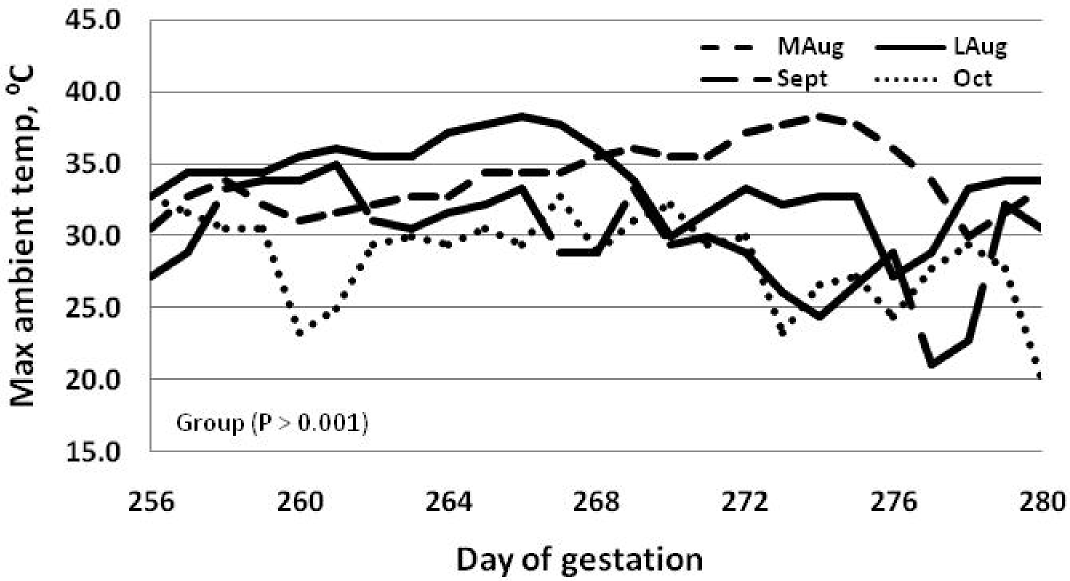

Figure 13. Maximum ambient temperature during 256 to 280 d of gestation for mid August, late August, September and October calving beef cows.

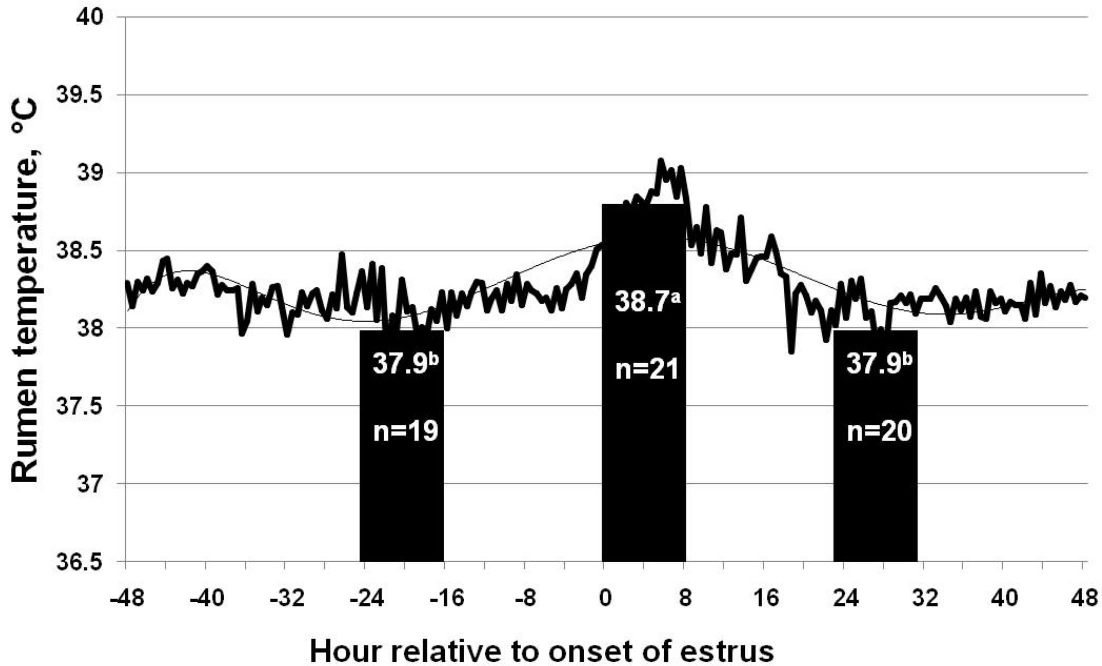

Figure 14. Rumen temperature 16 to 24 h before onset of estrus, during the first 8 h after onset, and at 24 to 32 h after the onset of estrus.

Table 5. Prediction of estrus using a change in rumen temperature ≥ 0.3 °C at the onset of estrus[a] compared with the same daily hours 24 h before the onset of estrus

Prediction for estrus	n	Percentage of cows predicted correctly
Rumen temp change ≥ 0.3 °C	15/18	83.3
Rumen temp ≥ 0.3 °C change when cow was anestrus	2/18	11.1
Rumen temp change ≤ 0.3 °C at estrus	1/18	6.0

[a]8 h period from onset of estrus was compared to same daily hr on the day before onset of estrus.

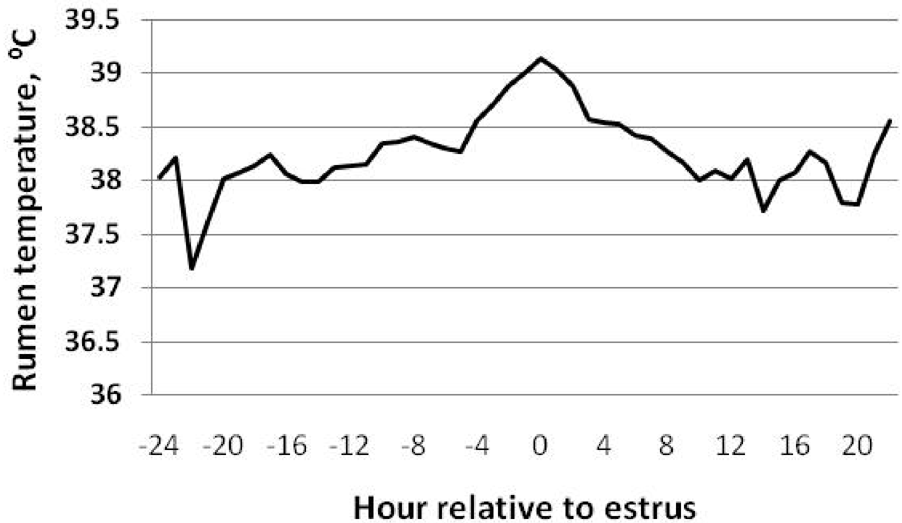

Figure 15. Rumen temperature in relation to onset of estrus (h 0) detected by Heat Watch®.

CHAPTER V

SUMMARY AND CONCLUSIONS

Elevated ambient temperature during late gestation shorten duration of gestation in beef cows. Changes in concentration of progesterone and estradiol in plasma were similar preceding parturition for cows with short gestations compared to those with a normal duration of gestation. Maternal concentration of cortisol increased due to exposure to elevated ambient temperatures in the first study but not the second study. This suggests that calves are still the initiator of parturition despite the stress on the cow and an increase in cortisol due to exposure to elevated ambient temperatures. Increased body temperature of cows may stress calves and initiate release of cortisol early or maternal cortisol released due to heat stress may be cross the placenta and influence developmental changes and alter initiation of parturition. A decrease in rumen temperature ≥ 0.3 ºC occurs in fall calving cows regardless of the ambient temperature in late gestation. The day of parturition can be predicted based on a decrease in rumen temperature 24 h before parturition. Rumen temperature at estrus increases ≥ 0.3 ºC in beef cows and this can be used to predict estrus. Production costs could be decreased with accurate prediction of onset of estrus for AI. Cattlemen could reduce calf lose due to dystocia with an accurate prediction of the day of parturition. This research provides evidence that change in rumen temperature can be used to predict both estrus and parturition.

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VITA

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Candidate for the Degree of

Master of Science

Thesis: EFFECTS OF AMBIENT TEMPERATURE ON DURATION OF GESTATION AND CHANGES IN RUMEN TEMPERATURE AT PARTURITION AND ESTRUS IN FALL CALVING BEEF COWS

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Title of Study: EFFECTS OF ELEVATED AMBIENT TEMPERARTURE ON DURATION OF GESTATION AND CHANGES IN TEMPERATURE AT PARTURITION AND ESTRUS

Pages in Study: 63 Candidate for the Degree of Master of Science

Major Field: Animal Science

Scope and Method of Study: Effect of ambient temperature on duration of gestation was evaluated in 24 fall calving Angus x Hereford cows during 2 yr. Cows were blocked according to age and AI to calve in August or October in yr 1. Cows were blocked according to age and AI to calve in mid August, late August, September, or October in yr 2. Plasma samples were taken for 2 wk prior to calving and concentrations of progesterone, cortisol and estradiol were assayed by RIA. Rumen temperature was recorded hourly at parturition and estrus in yr 2.

Findings and Conclusions: Cows exposed to elevated ambient temperatures during the last 2 wk of gestation have a shorter ($P < 0.05$) duration of gestation compared with cows not exposed to elevated ambient temperatures at this time. Concentrations of progesterone and estradiol in plasma are not altered by elevated ambient temperature. Concentrations of cortisol in plasma may be altered by exposure to elevated ambient temperatures. Rumen temperature decreases ≥ 0.3 ºC the day before parturition in fall calving beef cows. Rumen temperature increases ≥ 0.3 ºC at onset of estrus compared to the same daily hours on the day before onset of estrus. The change in rumen temperature can be used to predict parturition and estrus in beef cows.